

A Pilot Study of the Effects of Human Trampling on Rocky Intertidal Areas in Olympic National Park, USA

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Abstract

We examined the effects of human trampling on the rocky shoreline of Olympic National Park (ONP), Washington, to determine whether living intertidal resources are negatively impacted by recreational use. We sampled areas that experience high- and low-levels of human visitation and trampling pressure. We recorded percent cover of algae and sessile invertebrates, barnacle scars and bare space, and densities of motile animals. We measured basal diameters of the barnacle *Balanus glandula*, the grazing limpets *Lottia strigatella* and *L. digitalis*, and frond lengths of the fucoid alga *Fucus gardneri*. Preliminary analyses suggest that this coastline is affected by human trampling. Intertidal assemblages in areas of high visitation show reductions in fucoid algal cover and more barnacle scars and bare space than less-visited areas. Barnacle size distributions in the most-trampled areas are skewed toward smaller individuals.

Washington State can expect a 45% increase in total population over the next 30 years. This urban growth will be accompanied by an increasing demand for coastal recreation and consequent resource damage. Results of our research can be used by coastal managers in the Puget Sound and Georgia Basin to understand and offset the effects of human population growth in the region.

We examined the effects of human trampling on the rocky shoreline of Olympic National Park (ONP), Washington, to determine whether living intertidal resources in the Park have been negatively impacted by recreational use. We performed this research as a pilot study to identify study sites, test sampling methods, and gather data to guide a more intensive effort to be performed in summer 2003. Although this research was conducted on the outer Washington coast, these and future results can be used to guide management of rocky shores throughout the region.

The effects of human trampling on rocky intertidal habitats have been studied experimentally for less than two decades. Researchers have found that the diversity and abundance of species declines when rocky areas are subjected to trampling (Beauchamp and Gowing 1982; Povey and Keough 1991; Brosnan 1993; Keough and Quinn 1998; Brown and Taylor 1999; Schiel and Taylor 1999; Jenkins et al. 2002). Investigations in California and Oregon reveal that on frequently visited shorelines, plants and animals are smaller and turf algae and bare space dominate rocky substrata (Beauchamp and Gowing 1982; Brosnan and Crumrine 1992; Brosnan and Crumrine 1994). Expanded recreational use of coastal areas is thought to drive these changes. The rate of human population growth in the state of Washington is among the highest in the country (Campbell 1997), and an increase in demand for coastal recreation at publicly owned parks is expected to accompany this growth. ONP on the coast of Washington is a popular tourist destination located approximately 150 miles from the heavily populated Puget Sound basin.

We used a pairwise design to compare areas that experience high- and low-levels of human visitation and trampling on the coast of ONP. High-use (treatment) sites were accessible to foot traffic at moderate low tides. Water barriers and surge channels limited access to low-use (reference) sites. These paired sites were similar in elevation, exposure, substrate type and composition of surrounding substrate, levels of solar radiation or shading, and surface aspect. We sampled rockweed (*Fucus gardneri*) benches in two locations (Cape Alava and Norwegian Memorial), mussel beds (*Mytilus californianus*, *M. trossulus*) in one location (Hole-in-the-Wall), and the upper mid-littoral barnacle zone in four locations (Starfish Point, Toileak Point, Hole-in-the-Wall, and Yellow Banks).

Sampling was performed with randomly placed 20x20 cm quadrats, using 30 replicates in each treatment and reference site. We over-sampled all locations in order to determine optimal sample sizes for the 2003 season. We recorded percent cover of algae and sessile invertebrates, barnacle scars (basal plates of *Balanus glandula*) and bare rock, and densities of motile animals. We measured basal diameters of the barnacle *B. glandula*, and grazing limpets (*Lottia strigatella*, *L. digitalis*). We found that more accessible areas had greater percent cover of bare rock in five of the seven study locations (Figure 1); differences between treatment and reference sites at Toleak Point and Norwegian Memorial were not statistically significant. Percent cover of barnacles (pooled across species) was variable and differences were not statistically significant at $\alpha=0.05$ (Figure 2), however, we suspect that there are species-specific differences in barnacle cover and will measure individual species in the 2003 season. We found significantly more barnacle scars in accessible areas at Starfish Point, Yellow Banks and Toleak Point (Figure 3). The barnacle study location at Hole-in-the-Wall is lower in the intertidal zone than the other three barnacle locations, and the robust thatched barnacle, *S. cariosus*, is the dominant barnacle at this location. *S. cariosus* does not form a basal plate and so leaves no scar when removed from the substrate. Barnacles were consistently smaller in areas that are more accessible (Figs. 4 and 5).

In the 2003 season, our research will focus on the upper mid-littoral barnacle zone for three reasons. First, we've observed that people prefer to walk in the barnacle zone. This zone is exposed for a greater portion of the day than lower intertidal zones, and barnacles provide safe, secure footing for hikers. Second, as a dominant species in the upper mid-littoral zone barnacles are important members of the nearshore ecological community. The calcareous tests of adult barnacles create surface complexity, which buffers conspecifics and others from desiccation and thermal stress (Bertness 1989; Bertness and Leonard 1997), and provides refuge from predation to propagules of algae and other invertebrates (Gellor 1991; Kostylev 1996; Chiba and Noda 2000). Adult barnacles serve as prey for shorebirds (Irons et al. 1986) and predatory snails (Connell 1961; Connell 1970), and their pelagic larvae are eaten by juvenile fish (Gaines and Roughgarden 1987). Finally, because they can show morphological differences when repeatedly exposed to crushing impacts (Pentcheff 1991), barnacles are a good choice for measuring size distributions relative to human trampling pressure.

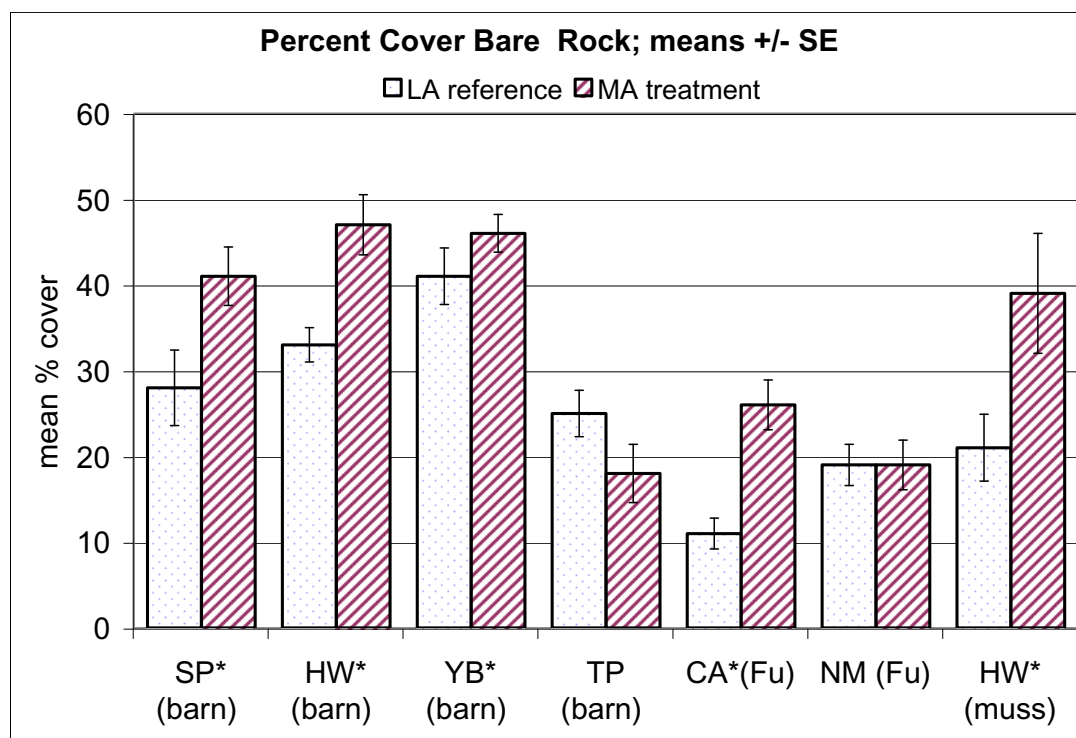


Figure 1. Percent cover of bare rock at all locations sampled on the ONP coast during the 2002 pilot study.

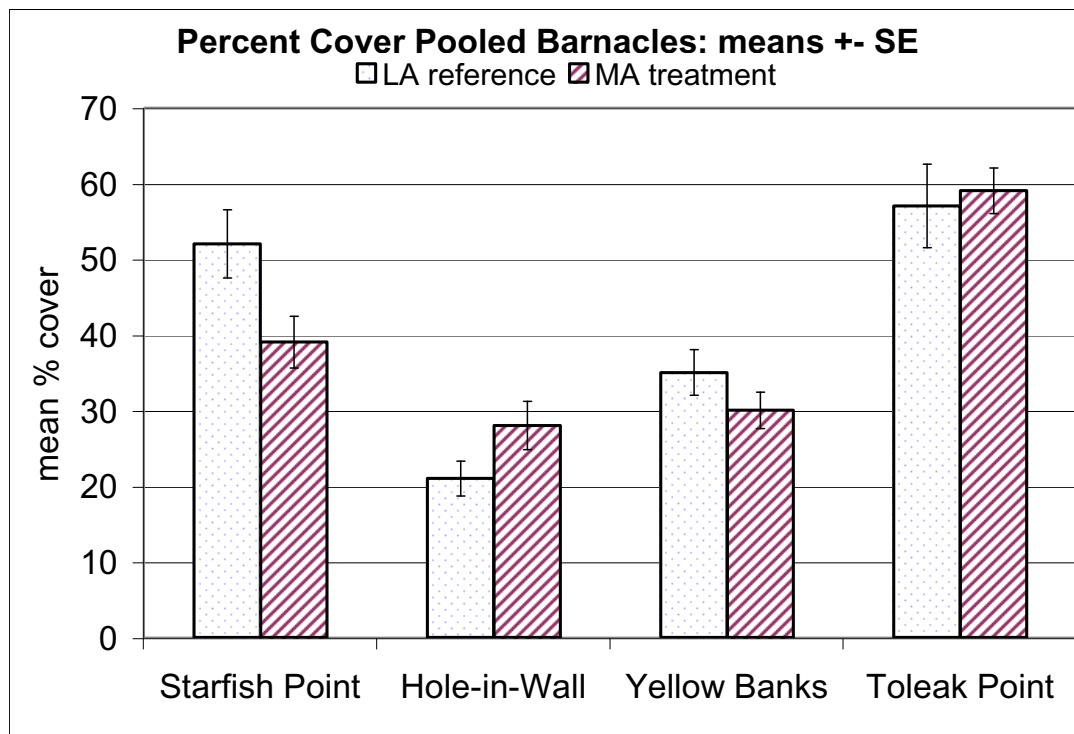


Figure 2. Percent cover of pooled barnacles (*Balanus glandula*, *Semibalanus cariosus*, *Chthamalus dalli*) at the four barnacle study locations.

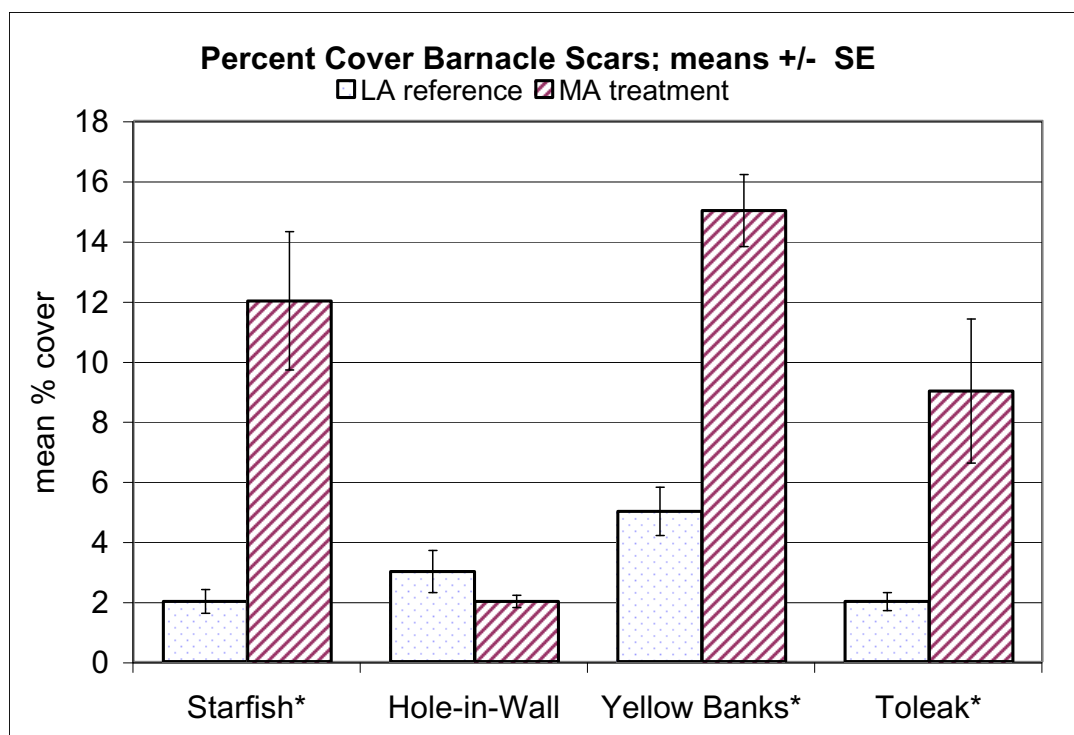


Figure 3. Percent cover of barnacle scars at the four barnacle study locations. *B. glandula* is the only barnacle of the three common barnacles on the ONP coast that leaves a calcareous basal plate when removed from the substrate. *B. glandula* is not the dominant barnacle at Hole-in-the-Wall.

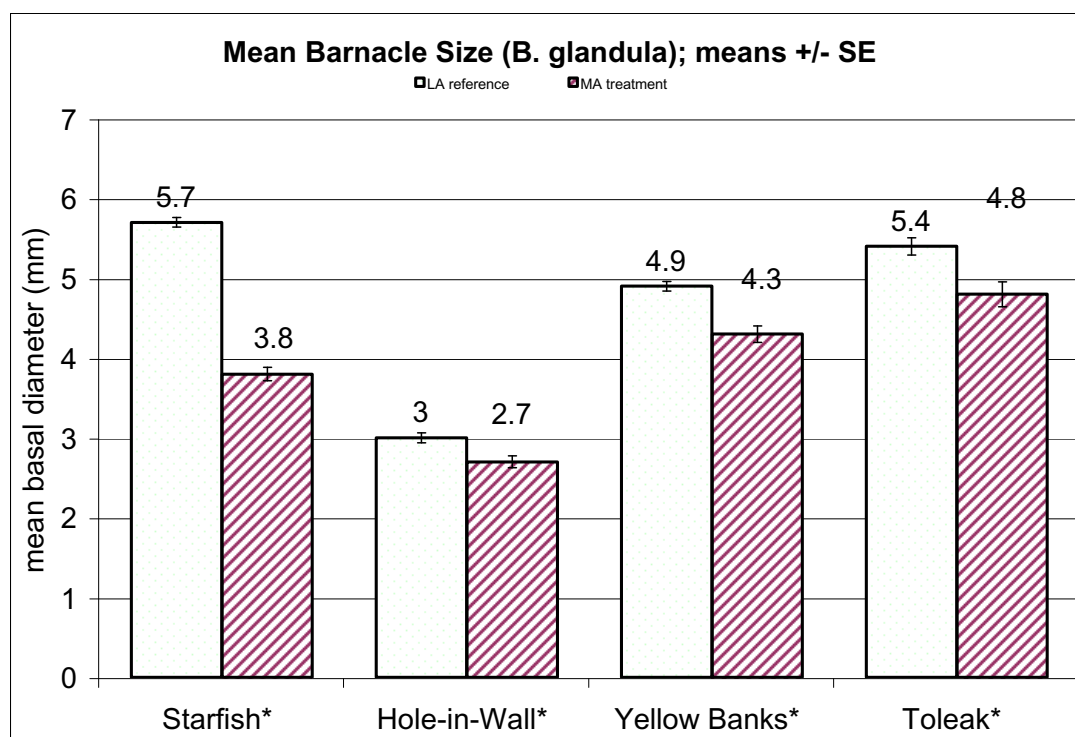


Figure 4. Mean basal diameters for the barnacle *B. glandula* at the four study locations in the barnacle zone.

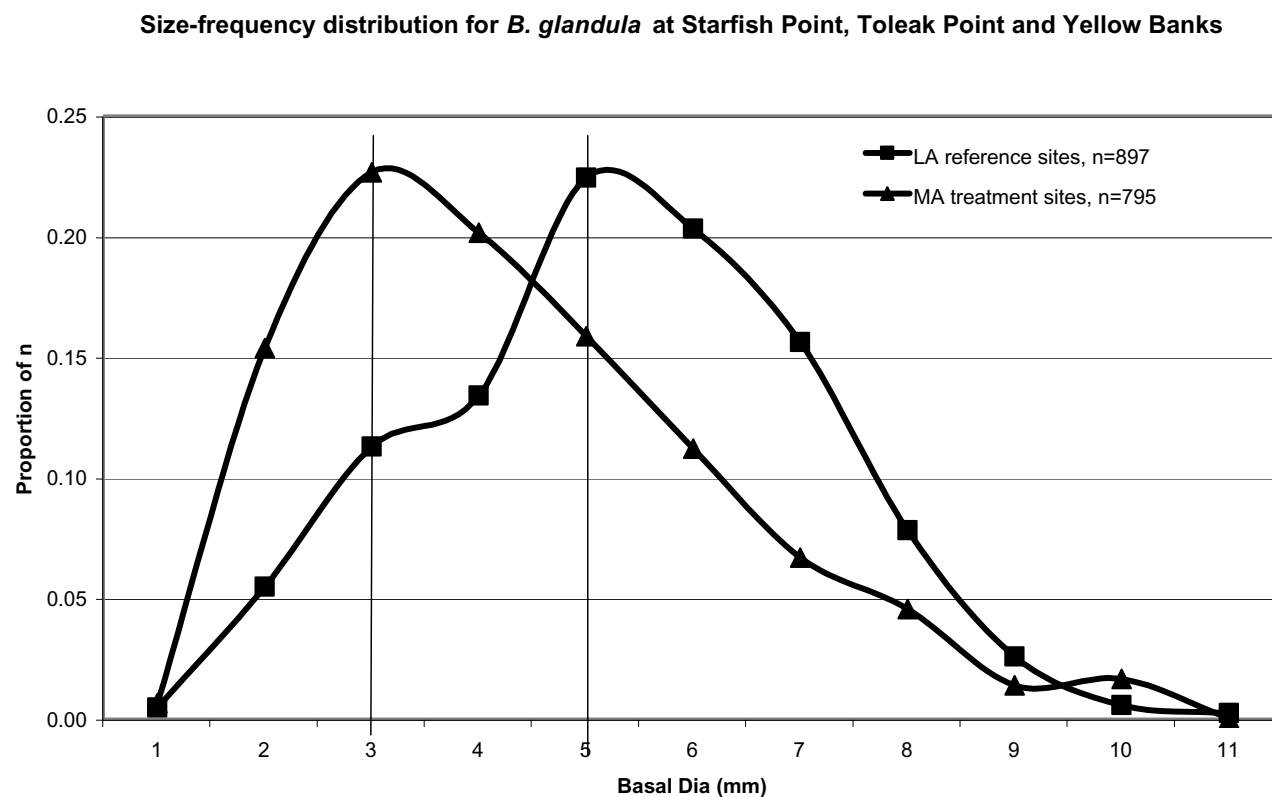


Figure 5. Size-frequency distributions for Starfish Point, Toleak Point, and Yellow Banks reveal that the treatment population is positively skewed whereas the untrampled shows a more normal distribution.

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